# OAR Support of the NWS

The NOAA Strategic Plan defines four science and technology (S&T)-dependent strategies to reach its goals. These strategies are also the process steps the NWS uses to sustain and improve the provision of weather, water, and climate forecast and warning products and services to the Nation. These steps are to: (1) Monitor and Observe; (2) Assess and Predict; (3) Engage, Advise, and Inform; and (4) Understand and Describe the atmosphere, oceans, lakes, rivers and other elements of the earth's environment. OAR critically supports the advancement of the NWS S&T baseline supporting these steps; and as a result of OAR R&D and related activities, the NWS produces better products and services for its customers with improved operational efficiency.

This document presents NWS needs in each of these four areas from the NWS Science and Technology Infusion Plan (STIP), and examples of how OAR activities have and continue to address these needs. These examples were gathered from the NWS Regions, National Centers for Environmental Prediction, and Headquarters Offices. The list is representative, but not exhaustive, of how OAR supports NWS' mission and strategic goals. Clearly, the high level of product and service quality the NWS provides the Nation would not exist without OAR's support.

**Monitor and Observe**: The NWS needs observational advances to improve forecast and warning accuracy. These advances include **new and higher space and time resolution measurements** of critical environmental elements. Improved **data quality and timeliness** with long-term continuity are also necessary to improve forecasts and warnings, reduce observational and analysis error, and ensure a long-term climate record. Observational systems and networks need to be integrated into **enterprise architectures** to improve efficiency and provide timely data access.

Examples of OAR activities in support of NWS needs in the M&O category include:

WSR-88D Algorithm Development: NSSL led the development of a suite of automated radar storm algorithms which are now the basis for operational WSR-88D software used for severe storm detection and analysis. This has been a critical factor in improving severe weather performance scores (e.g., probability of detection).

WSR-88D Open Systems: Continuing applied research in weather radar applications at NSSL, in conjunction with the NEXRAD Radar Operations Center, resulted directly in WSR-88D Open System modifications which have been implemented operationally and will provide improved efficiency and accuracy from the system.

Quality Control and Use of WSR-88D Data: NSSL is leading a research project to improve quality control and use of WSR-88D data in numerical models. This project will benefit NCEP operational models since the radar network is one of the few truly high-resolution space and time operational observing systems covering the continent.

Dual Polarization Radar: NSSL is leading the development of dual-polarization radar capabilities which will provide greatly improved precipitation estimates critical to the NWS Hydrology program and new meteorological observation capabilities. This development effort is programmed for operational implementation later in the decade.

Hurricane Wind Monitoring: AOML/HRD provided leadership in working with the research community to introduce the Stepped Frequency Microwave Radiometer as the only successful remote-sensing tool to sample surface winds in and near the core of hurricanes. This instrument is flown aboard NOAA P-3 research aircraft and provides critical surface wind data to hurricane forecasters.

Gulfstream IV(G-IV) Instrumentation: HRD and ETL personnel partnered in designing the new G-IV instrumentation now being built with NOAA funds. The information provided will help improve operational hurricane model and forecast performance.

Dropsondes: AOML/HRD pioneered aircraft and dropsonde surveillance techniques leading to NOAA's investment in G-IV/dropsonde missions. These data were key to improvements of numerical model track forecasts of ~20%.

Winter Storm Reconnaissance Support: ETL scientists have led and participated in field programs in the Northeast Pacific, such as CalJET, PacJet, and NCEP's operational Winter Storms Reconnaissance program. CalJet and PacJet provided important new understanding and data, which contributed to improving operational west coast precipitation forecasts. The WSR program continues to provide data needed by numerical models to reduce track and intensity errors of large extratropical storm systems.

Wind Profiler Program: FSL led the effort to site, maintain, and provide data of the highest quality and operational usefulness from the profilers. NCEP/Storm Prediction Center (SPC) and FSL collaborate to develop algorithms for the use of Wind Profiler Network data in routine SPC forecast operations. Wind profiler data are important for improved forecasts of severe convective weather events and other small-scale weather events.

GPS Moisture Soundings: FSL is prototyping a system which gathers GPS data from a variety of agencies nationwide to derive atmospheric moisture profiles at high time resolutions. These data are of high quality and are used routinely by Weather Forecast Offices (WFOs). NCEP/SPC and FSL develop analysis techniques to incorporate network data into the SPC's continuous weather watch. These data help fill the gaps in the operational radiosonde network and provide data important for severe weather and QPF forecasts.

ENSO Monitoring and Predictions: Most of the tropical SST and sub-surface ocean data utilized by the NCEP/Climate Prediction Center (CPC) and the Global Ocean Data Assimilation System (GODAS) comes from the TAO array of buoys in the equatorial tropical oceans developed and maintained by PMEL. Data from the TAO array, either in its raw form or after it has been ingested into GODAS, is the underpinning for analyzing and predicting the tropical Pacific SST variability.

Ozone Monitoring: NCEP/CPC's effort in monitoring the atmospheric concentration of ozone depends critically on the data provided by CMDL.

Tsunami Monitoring: PMEL developed and maintain the Deep-Ocean Assessment and Reporting of Tsunamis (DART) buoys in the Pacific, as well as critical administrative support for the highly-successful National Tsunami Hazard Mitigation Program.

Space Weather Observations: As part of NCEP, SEC continuously monitors and analyzes the environment between the Sun and Earth. SEC receives solar and geophysical data in real time from a large number of ground-based observatories and satellite sensors around the world and translates the information into forecasts and warnings.

**Assess and Predict**: The NWS needs advanced **data assimilation techniques** to improve the quality of analyses and model initialization and to maximize the value of existing and new observational data sets. Common **modeling systems** are needed to increase the transfer rate of research into operations. Advanced ensemble modeling techniques are needed to generate

probabilistic forecasts. Advanced **processing** with new statistical techniques is needed to account for model biases and further improve the quality of model output. Advances in **decision support systems** and real-time gridded verification capabilities are needed to improve forecast and warning accuracy and specificity. New **science applications** are needed to support advanced **digital forecast and warning product** quality and preparation efficiency. Concomitant advances in **information technology** are critical to support observations, data assimilation and modeling systems, forecast applications and preparation tools, communications, and dissemination systems.

Examples of OAR activities in support of NWS needs in the A&P strategy include:

*Data Assimilation and Modeling*

Hurricane Model Development: The operational NWS hurricane model was developed at GFDL and transferred to NCEP operations. The model continues to be upgraded by GFDL. The implementation of the hurricane model has contributed significantly to the improvement in operational forecasts over the past decade.

Hurricane Intensity Forecasts: AOML/HRD developed and maintains the only skillful operational hurricane intensity forecast scheme (SHIPS). The model provides key information needed to develop hurricane intensity forecasts.

RUC Development: The RUC model system, which provides operational atmospheric analyses and short-term forecasts over the CONUS to support tactical aviation and severe weather forecasts, was developed at FSL and transferred to NCEP operations. The RUC continues to be sustained and upgraded by FSL.

LAPS Development: FSL developed LAPS which is used extensively on AWIPS to incorporate local observations. LAPS integrates data from virtually every meteorological observation system into a very high-resolution gridded framework centered on a forecast office's domain of responsibility.

WRF Development: FSL has built a major component of the Weather Research and Forecast modeling system, which will become the new operational NWS prediction model later this decade.

Flash Floods/Hydrology: NSSL completed basin-delineation for the continental United States, a critical component of the Flash Flood and Monitoring Prediction (FFMP), a component of the NWS Advanced Hydrologic Prediction Service. FFMP zeroes in on the precise creeks where flash flooding occurs, mitigating the loss of life and property.

Intraseasonal to Interannual Hydrologic Prediction: Research collaborations between NWS/OHD and NCEP and CDC has produced significant improvements to surface-atmosphere interaction models and innovations in hydrologic models for long-term streamflow prediction.

Doppler Radar Data Assimilation: AOML/HRD is partnering with the NCEP/Environmental Modeling Center to prepare Doppler Radar data sets for experimental data assimilation in hurricane applications. HRD's unique knowledge of the instrument is key in developing quality control algorithms and in devising compression techniques for data transmission from the G-IV reconnaissance aircraft. This allows more of these important data to be processed in operational data assimilation schemes and results in improved forecasts.

Land-Surface Model Validation: The 6-station SURFRAD network developed and maintained by ARL has been critical to NCEP/EMC's land surface model development by providing observations

to validate the surface solar insolation biases in the Eta/EDAS and in the GFS. This information is used to upgrade and improve the performance of these models.

Earth System Modeling Framework: GFDL is collaborating with NCEP and others to build community-wide software for both operational and research numerical model and data assimilation systems. This will provide the basis for improved transition of research into operations.

Energy Project: Major collaborations are in progress among FSL, NSSL, ETL, and NWS to improve summertime forecasts in New England. The improved ensemble-modeling and other forecasting techniques resulting from this project will be transitioned to operations.

Ocean Model and Data Assimilation Support: Versions of GFDL's Modular Ocean Model have been ported to NCEP's computer to support development and execution of NCEP's Seasonal to Interannual Forecast mission.

*Forecast Products and Techniques*

Air Quality Forecasting: NCEP/EMC and ARL are partnering to develop an operational Air Quality (AQ) forecasting model. Air quality codes developed by ARL have been transitioned to run operationally at NCEP.

Hurricane Outlooks: Research conducted at HRD is crucial in improving seasonal hurricane outlooks at NCEP/CPC. Long-range hurricane outlooks are produced by CPC forecasters in consultation with experts in the other part of NOAA, including researchers at AOML/HRD.

Seasonal Precipitation and Surface Temperature Outlooks: NCEP/CPC forecasters routinely consult with research scientists from CDC and GFDL and draw upon their expertise while preparing seasonal climate outlooks and discussing current and expected climate regimes.

Severe Weather Climatologies: Detailed climatologies of tornadoes, large hail, and damaging thunderstorm wind gusts have been developed collaboratively by SPC and NSSL. This information is used to provide new understanding and operational guidance to severe weather forecasters at SPC and across the country.

Verification Data for UV Forecasts: NCEP/CPC produces a daily prediction for the Ultra-Violet (UV) index over North America. The utility of UV forecasts produced by CPC are verified against actual UV measurements by maintained by ARL, leading to forecast refinement and improvement.

Development of Dual-Polarization Precipitation Estimation Algorithms: A prototype precipitation algorithm at NSSL run in real time has demonstrated consistent incremental improvement over existing WSR-88D Precipitation Processing System products. Prototype algorithm development and testing provides NWS and NOAA leadership the information needed to make decisions about future observational systems.

Multi-Sensor Quantitative Precipitation Algorithms: NWS/Office of Hydrological Development (OHD) and NSSL are working jointly to objectively compare multi-sensor precipitation estimation algorithms. Knowledge gained will be used to develop improved operational techniques.

Aviation Forecast Verification: FSL's Forecast Verification Branch provides verification information which allows NCEP/Aviation Weather Center (AWC) to discern various characteristics regarding forecasts including accuracy, area affected, and volume of airspace affected. The FSL/Quality Assurance Group provides verification information to the developers of aviation

forecast products which will eventually become part of the AWC's operational product suite.

Aviation Weather/Volcanic Ash: FSL developed a prototype Volcanic Ash Coordination Tool for Alaska, allowing NWS Alaska Aviation Advisory Unit to coordinate with the Anchorage CWSU and the USGS Alaska Volcano Observatory on volcanic ash events.

*Field IT*

AWIPS-Display 2-Dimensional (D2D): FSL developed D2D and associated "under the hood" AWIPS infrastructure. D2D is the integrating work environment (e.g., multiple overlays of observations and guidance organized by time and space and meteorological calculations), by which NWS forecasters monitor key weather and hydrologic information and events and issue warnings. Display 3-Dimensional (D3D), which will allow the NWS to more efficiently process and interpret larger volumes of information, is currently under development by FSL.

Linux Solution for AWIPS: FSL developed and transitioned, and continues to support, the implementation of AWIPS on the Linux operating system. Linux is a cost effective open-systems environment that allows the NWS to run numerically-intensive warning decision aids.

IFPS/GFE: FSL developed the graphical forecast editor (GFE), a key component of IFPS, and a robust library for building smart tools. GFE is essential for the generation of NDFD grids, a major new the NWS forecast product being implemented operationally in 2003-04.

Data Ingest: FSL developed and maintains the Meteorological Assimilation Data Ingest System which provides quality-controlled, high resolution data in support of NWS forecast operations, including data assimilation, numerical weather prediction, and other hydrometeorological applications.

Warning Decision Support: NSSL developed the Warning Decision Support System (WDSS). WDSS is the prototype for SCAN, a key warning decision support tool used operationally on AWIPS.

**Engage, Advise, and Inform:** Advanced, universally-accessible **dissemination technologies** are needed by the NWS to deliver environmental information for the protection of life and property. A comprehensive **digital database** with easy user access is needed to keep up with the ever increasing demand for environmental information. Confidence measures and other uncertainty information are needed for all forecast parameters and at any location, allowing users to make environmental decisions based on their level of risk tolerance. Users need **data-mining tools** to probe the database and decision tools to exploit it.

Examples of OAR activities in support of NWS needs in EA&O include:

Aviation Forecast Coordination: FSL is developing the new technology needed for mass coordination among the AWC and WFOs. This will allow interaction between central and local forecasters during key aviation weather events.

Inundation Mapping: PMEL assists in providing detailed maps of future flooding (inundation) maps. These maps are needed for delineation of evacuation routes and long-term planning in vulnerable coastal communities used operationally across the country.

Data Mining and Delivery: Data mining and delivery for wind profilers and surface mesonet data were initiated by FSL. FSL also lead the effort to obtain MDCRS data. The FSL effort includes collecting the data, applying preliminary quality control, formatting, and delivery to NWS operations at NCEP.

FX-Collaborate: This FSL-developed system provides the ability to view and annotate meteorological data, greatly facilitating inter-office and inter-agency collaboration during critical weather events.

FX-Net: FSL developed FX-NET, which provides the capability for remotely-located forecasters (e.g., Alaska Region WFOs) to access AWIPS-like displays via a laptop. It is frequently used to support the fire weather IMETS.

**Understand and Describe**: New **technologies and techniques** are needed by the NWS to improve environmental forecasts and warnings. **Observational deployment strategies** need to be developed that cost-effectively meet NOAA's mission through integrated observing systems. New **tools** are needed to support **digital forecast preparation and user access**. Improved understanding of **predictability and improved statistical and ensemble models** are needed to enable "warnings based on probabilistic forecasts. New **understanding and models** of processes and linkages among geophysical, chemical, biological, and anthropogenic systems are necessary to support new weather-, water-, and climate-impact forecast products. Research is also needed to anticipate **changing social and economic needs** that require new products and services.

Examples of OAR activities in support of NWS needs in the U&D strategy include:

Research in Understanding Climate Variability: Several OAR labs (AOML, PMEL, CDC, GFDL) have a special focus on understanding aspects of climate variability on different spatial and temporal time scales. Results from such research leads to improvements in climate outlooks and forecasts issued by the CPC.

Hurricane Field Program: The AOML/HRD field program generates unique observations in tropical cyclones, necessary for the research and operational meteorological communities to better understand, describe, simulate and forecast tropical cyclones.

Hydromteorological Testbed: ETL partnered with NCEP/HPC in creating the Hydrometeorogical Testbed. This effort serves to infuse the latest science research results into NCEP and WFO forecast operations.

Hazardous Weather Forecast Testbed: NCEP/SPC collaborates with NSSL for assessing science-based improvements to hazardous weather forecasting. This effort serves to infuse the latest science research results into SPC forecast operations.

Doppler Radar Research: Applied research at NSSL in the field of Doppler radar use in weather applications; the joint Doppler project (JDOP) in the late 1970s led directly to WSR-88D design and deployment.

WSR-88D Algorithm Testing and Display System (WATADS): NSSL developed WATADS which provides NWS Science Officers the capability to conduct local research projects using Doppler radar data.

General Training Efforts: OAR scientists have been actively involved as instructors in the NWS Warning Decision Training course at COMET and in training workshops on the use of the GFE and smart tool development and smart initialization.

SPC Forecaster Training Program: NSSL research scientists serve as subject matter experts, make presentations, and conduct workshops in this program. These interactions have directly contributed to enhancements in science-based forecasting at SPC.